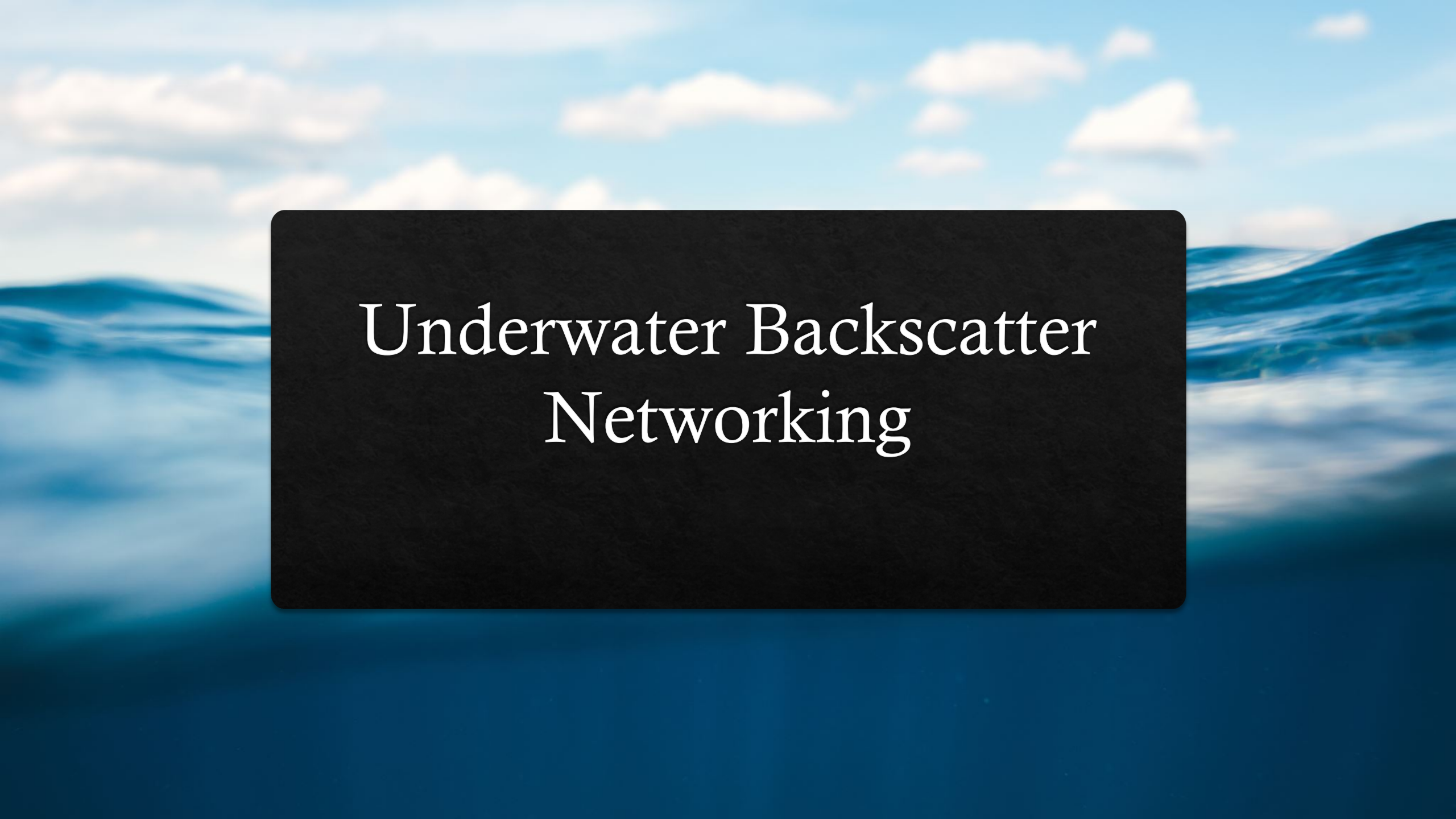

Underwater Backscatter
Networking

# Motivation

Deploy Ocean Sensors for Scientific Exploration

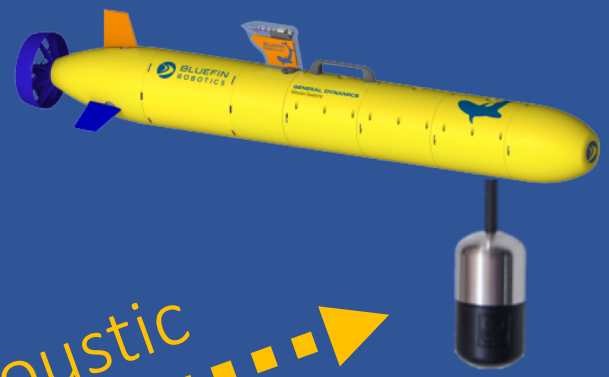
Underwater Climate Monitoring

Marine Life Sensing

Underwater communication is power hungry

# Traditional Approach

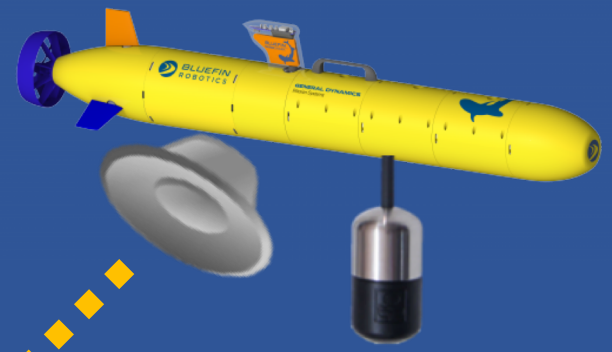
Underwater Drone



Acoustic

Sensor generates its own acoustic signal

# Our Technology



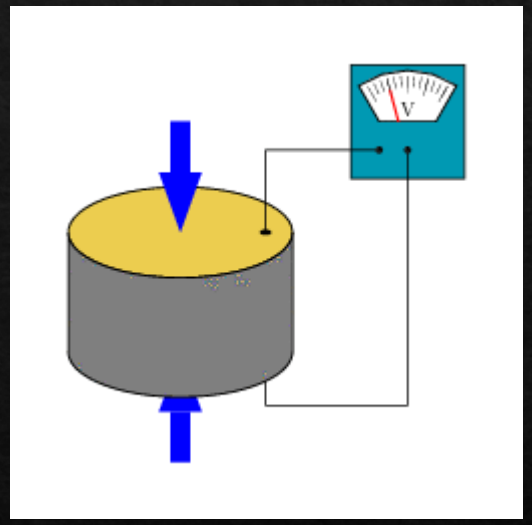
Acoustic

Sensor reflects an existing acoustic signal

How can PAB transform acoustic waves into electric signals and vice versa?

# Piezo-Electricity

Property of some materials to convert mechanical strain into electricity




$$P = \alpha V \sin(2\pi f t + \phi)$$

How can the piezo be converted into a reflector?

# Reflective State

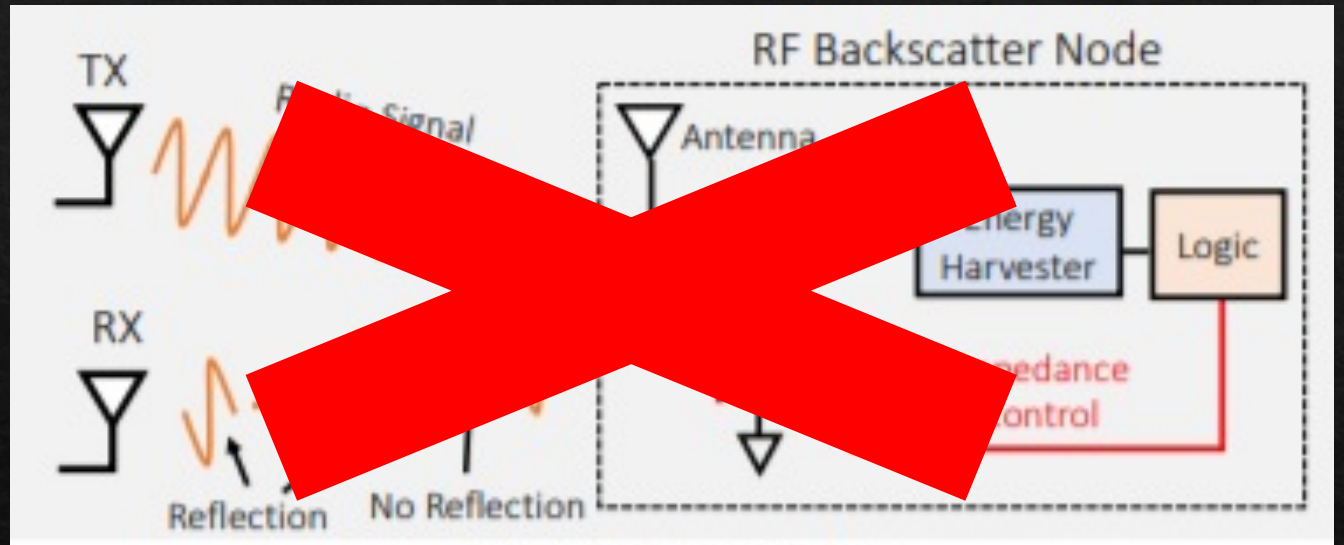
$$\underbrace{D}_{\text{charge displacement}} = \underbrace{dT}_{\text{mechanical}} + \underbrace{\epsilon^T E}_{\text{electrical}}$$

When the terminals are shorted:
E = 0
D = 0
Thus, T = 0

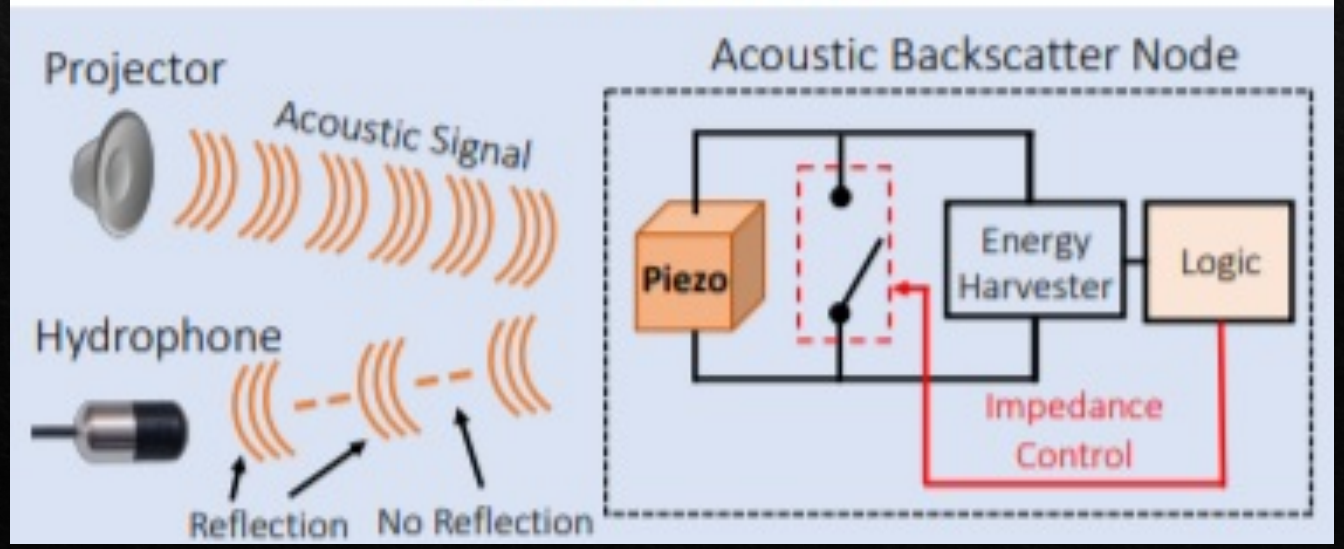
Since T is the total mechanical stress. That is stress from incoming wave plus stress from the reflected wave.

Thus the piezo reflects by not being able to deform.

# Backscatter

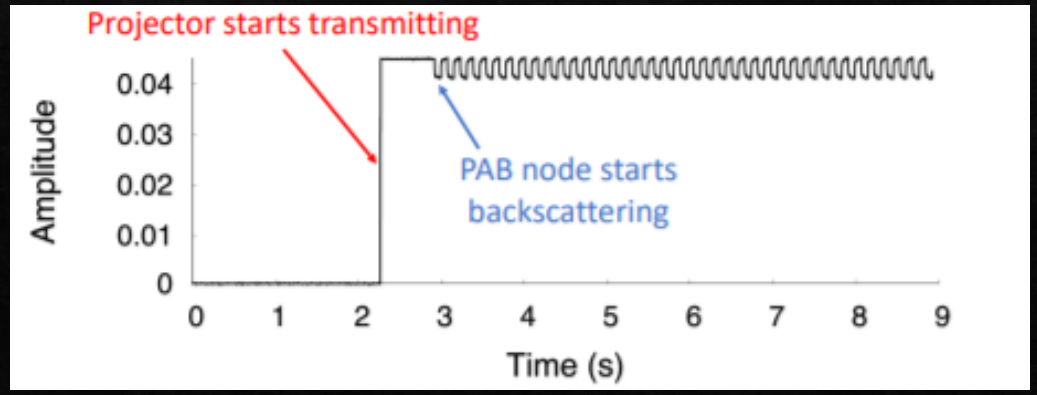



(a) RF Backscatter in Air




RF signals decay exponentially in water

Why doesn't it completely go to zero in absorptive state?



# Hardware

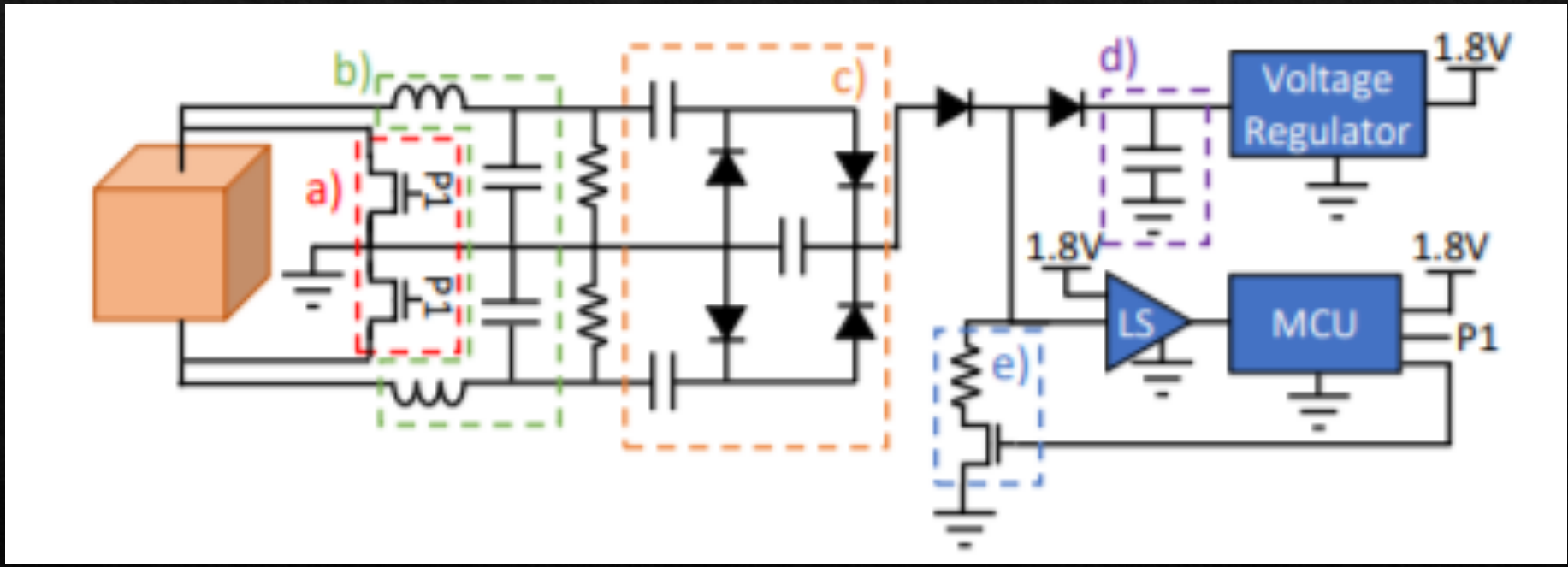
Primary purposes:

1-Backscatter communication

2-Energy harvesting

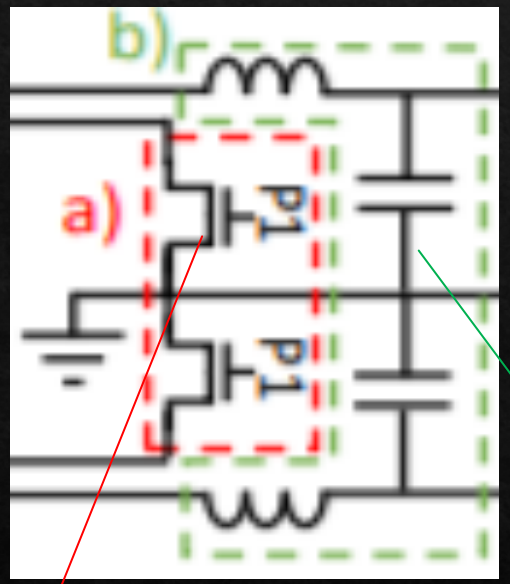
3-Receiving and decoding

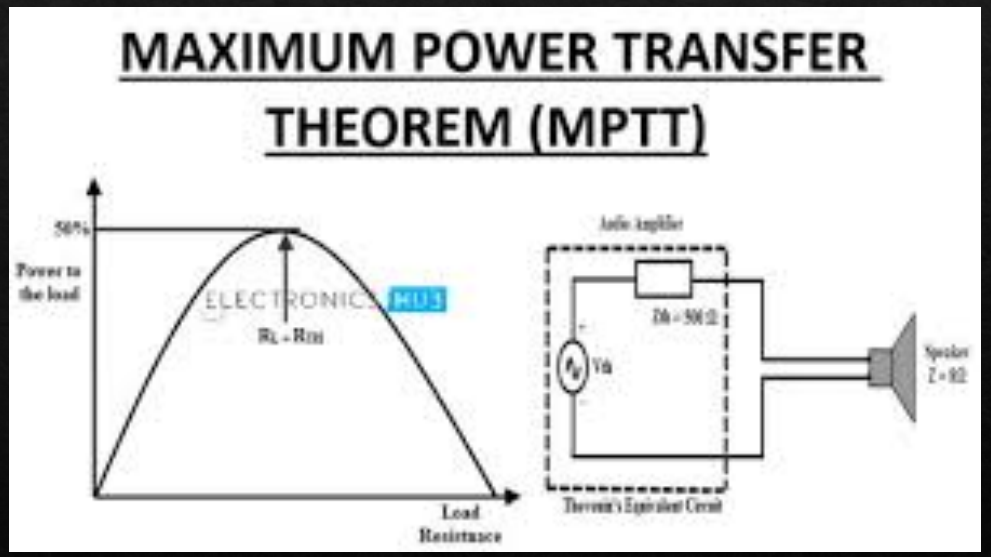
4-Interfacing with peripherals.



# Impedance Matching Network

Objective: Ensure maximum power transfer and better SNR



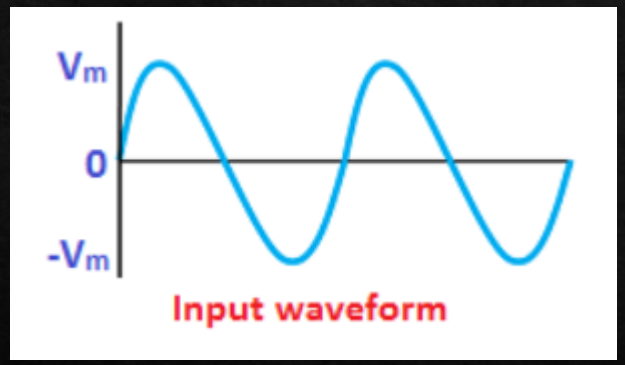

Backscatter switches:

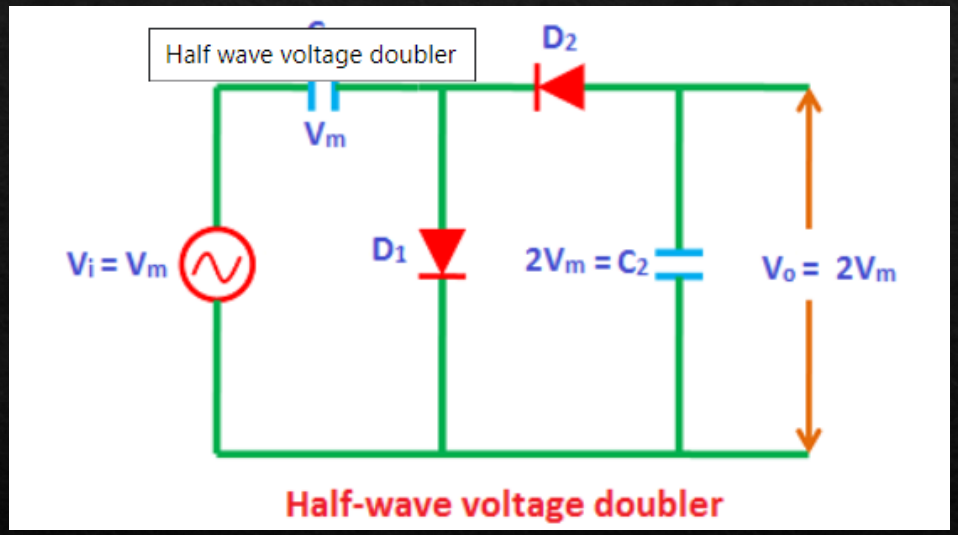
- Two MOSFETS in series

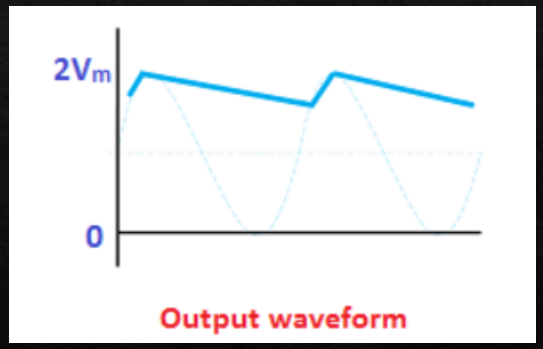
Impedance matching

- Inductors and capacitors

# Energy Harvesting



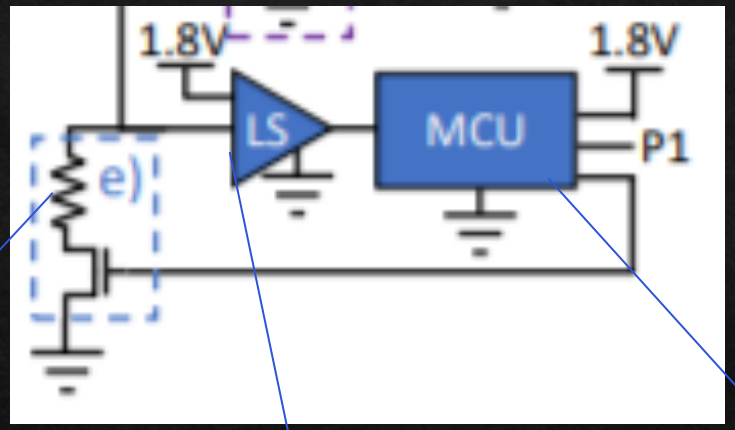




1-Rectifies
2-Doubles the amplitude

Why need to rectify?

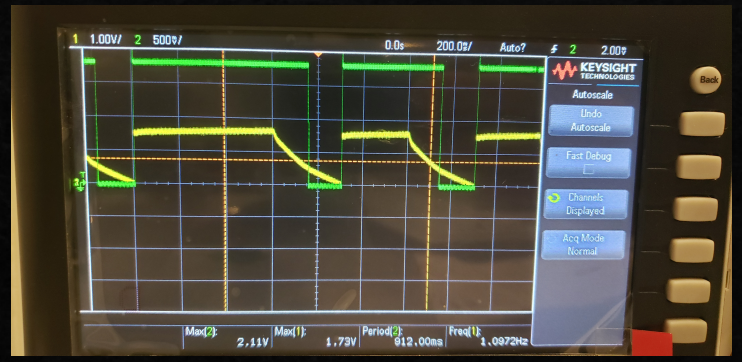
Why need to double voltage while energy remains the same?

# Downlink Decoder




Pull-down resistor

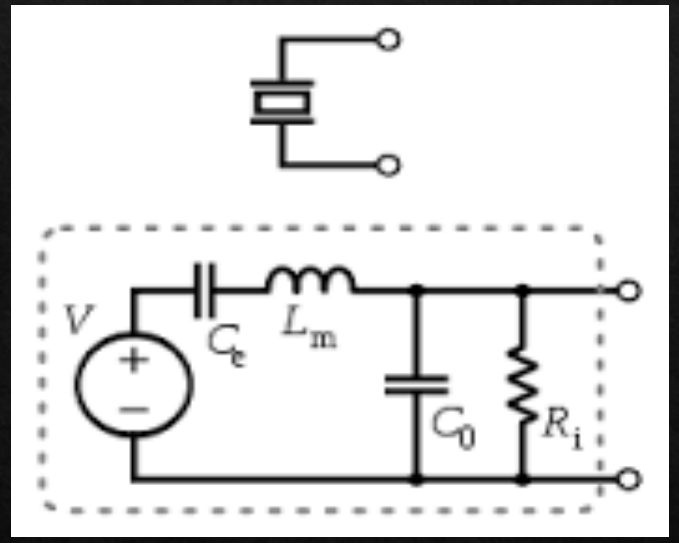
Level shifter and
Schmitt trigger



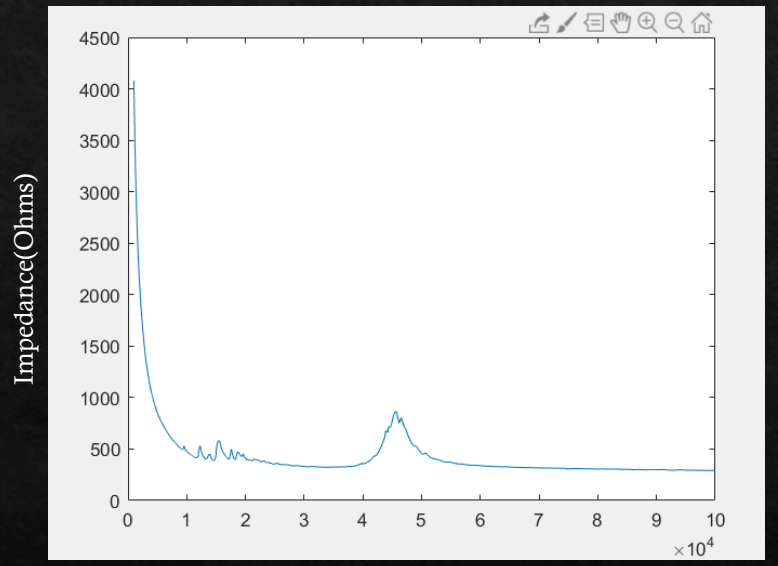

Microcontroller

- Edge detection
- Ultralow power microcontroller, MSPG2553
- consumes less than 230 μA at 1.8V

# Narrow bandwidth

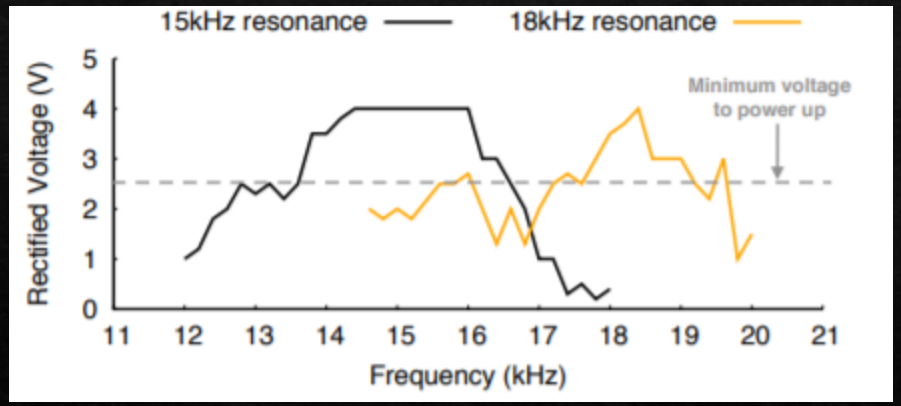



Piezoelectric model



# Overcoming narrow BW

Recto-Piezos Idea: Having other sensors whose piezos resonate at a different frequency




Backscatter communication is frequency agnostic

$$y(f_1) = h_1(f_1)x_1 + h_2(f_1)x_2$$
$$y(f_2) = h_1(f_2)x_1 + h_2(f_2)x_2$$

Concurrent transmissions solving two equations with two unknowns

- Know the channel matrix because the preamble is known
- Know received signal

# Uplink Decoder

1- MATLAB-based decoder. The decoder identifies the different transmitted frequencies on the downlink using FFT and peak detection.

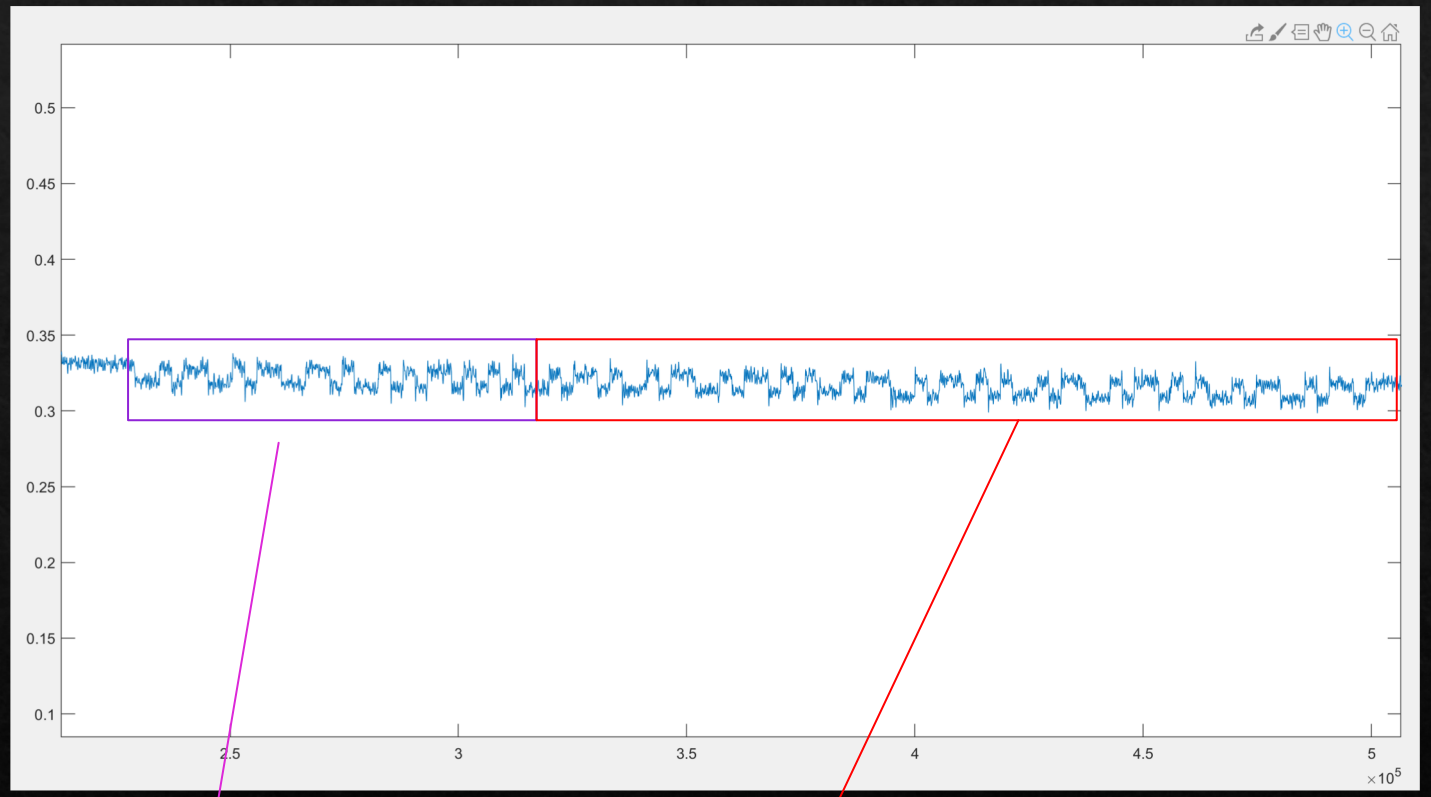
2- Then downconverts the signal to baseband by multiplying by its respective carrier frequency.

3- Employs a Butterworth filter on each of the receive channels to isolate the signal of interest and reduce interference from concurrent transmissions.

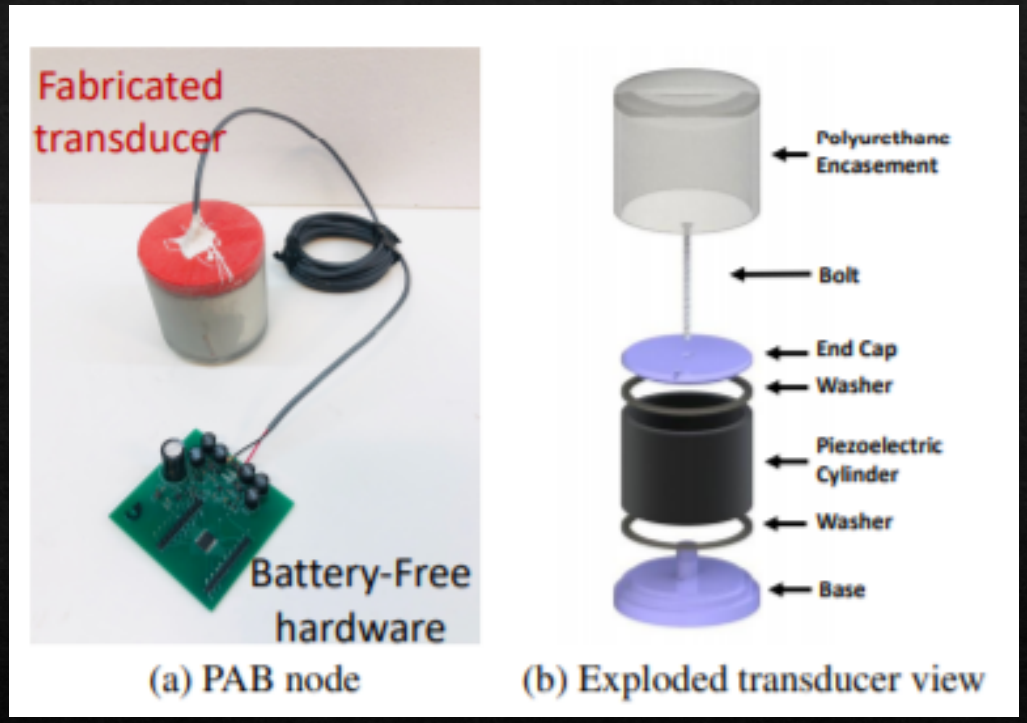
4- Employs a maximum likelihood decoder to decode the FM0 decoded bits

$$\sin\alpha \sin\beta = \frac{1}{2}[\cos(\alpha - \beta) - \cos(\alpha + \beta)]$$

# After downconversion

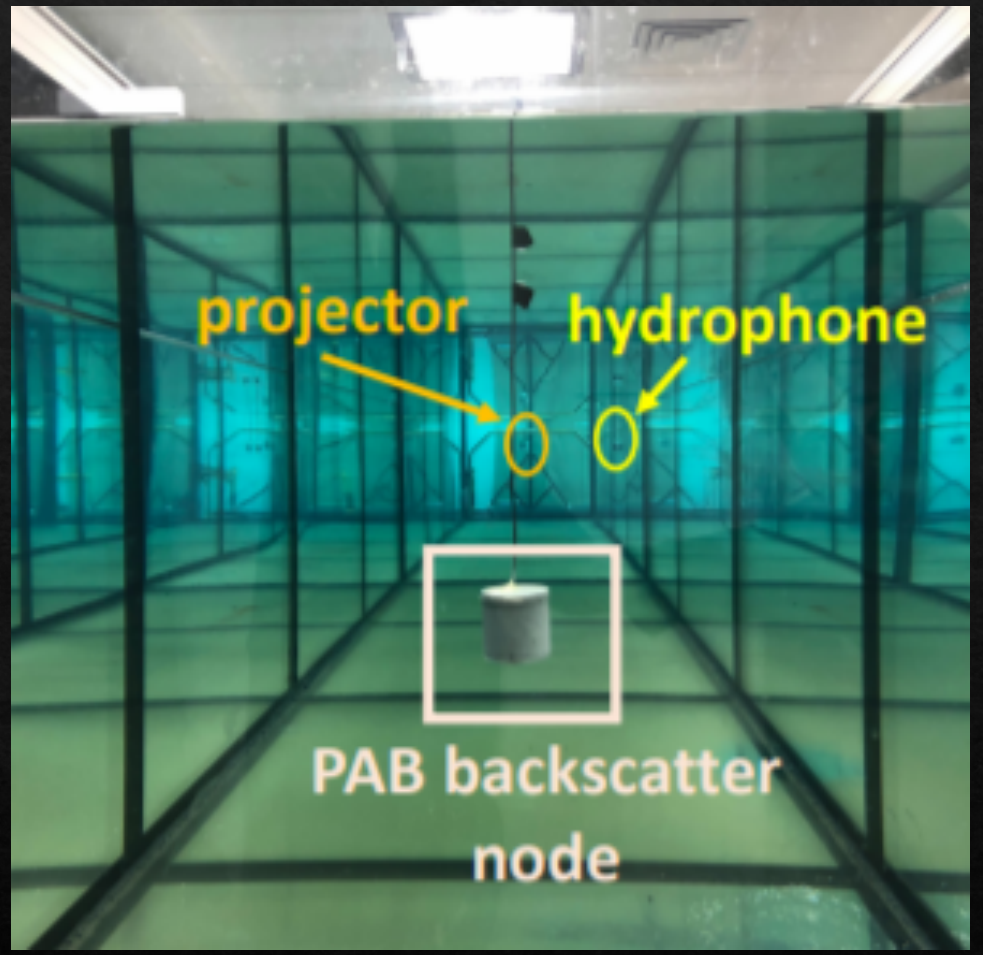


# Mechanical Fabrication



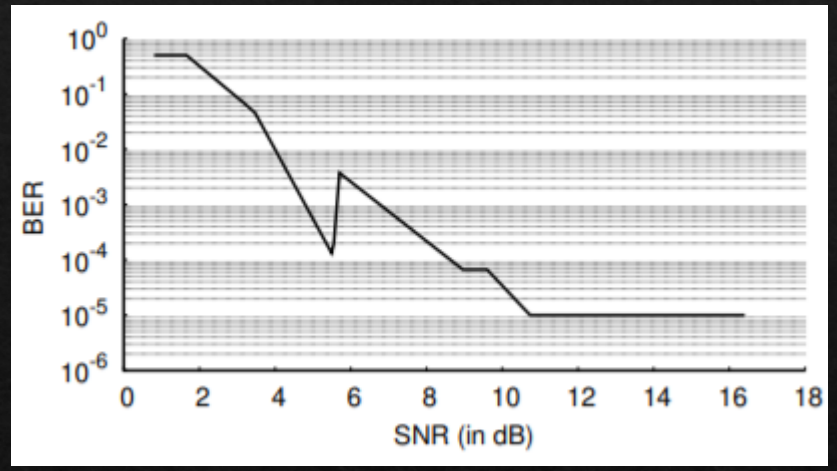

Air-backed, end-capped transducer

# Evaluation



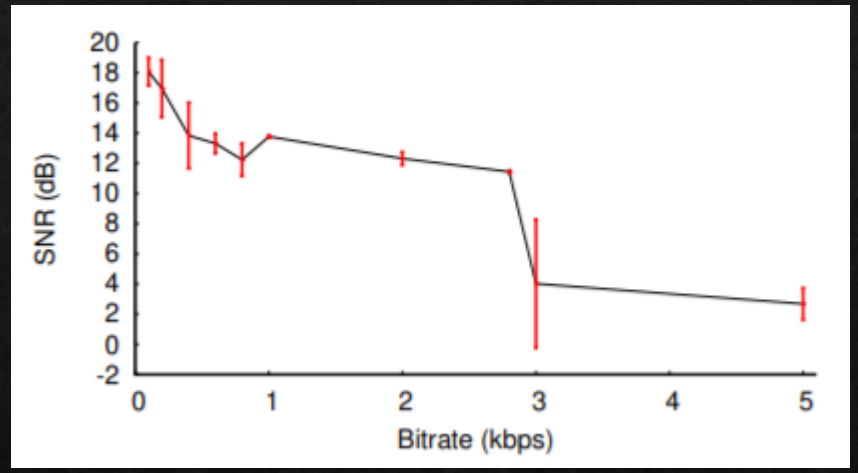

Tested in closed water tanks

# Results




Testing communication

- The decoder is able to decode with a minimum SNR around 2 dB
- The BER drops to 10□ 5 at SNRs higher than 11 dB




- The SNR decreases when the bitrate increases
- The SNR significantly drops for bitrates higher than 3 kbps

# Results

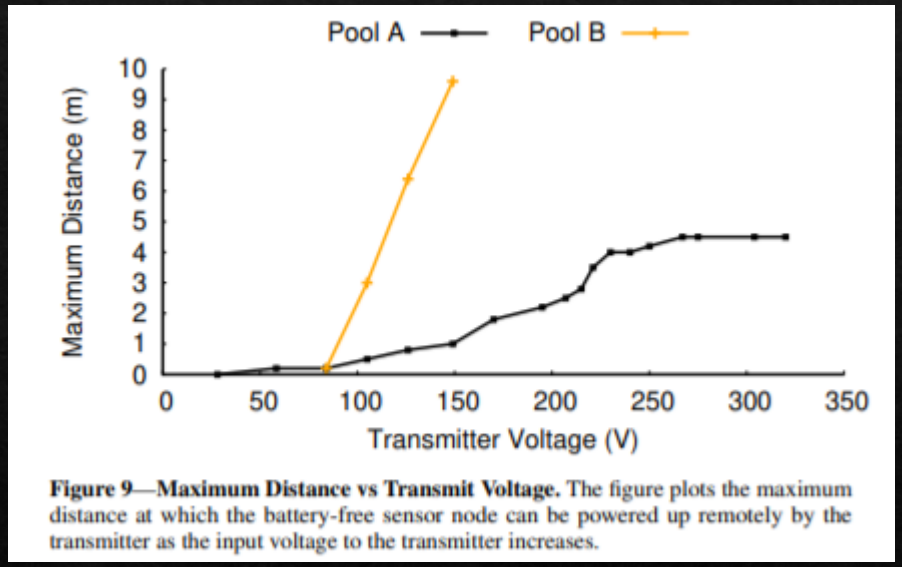



**Figure 9—Maximum Distance vs Transmit Voltage.** The figure plots the maximum distance at which the battery-free sensor node can be powered up remotely by the transmitter as the input voltage to the transmitter increases.

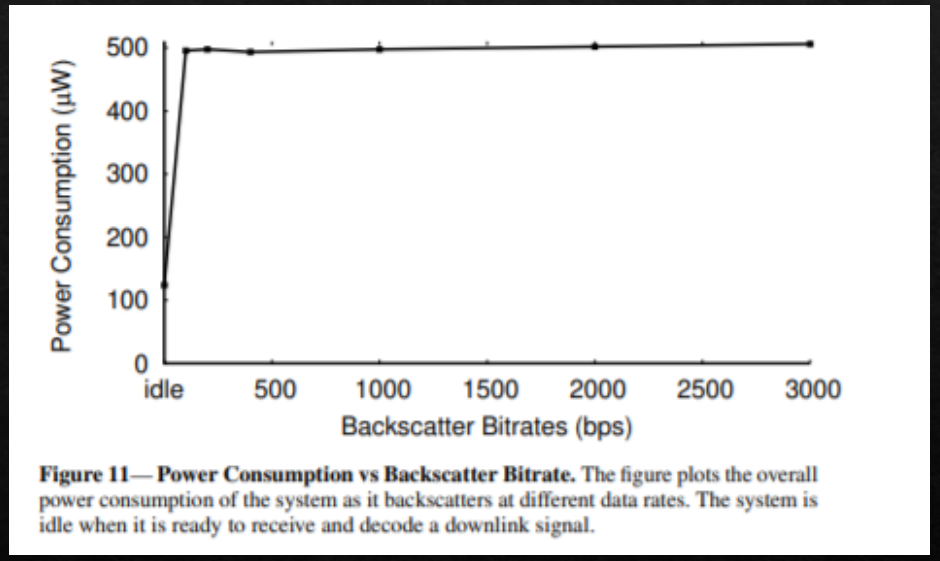



**Figure 11— Power Consumption vs Backscatter Bitrate.** The figure plots the overall power consumption of the system as it backscatters at different data rates. The system is idle when it is ready to receive and decode a downlink signal.

- Idle or lazy state consumes 124µW
- Power consumption increases to around 500µW for the different backscatter bitrates